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Analysis of the Economic and Environmental Effects by the Offshore Wind Power Construction: In case of Kitakyushu City, Japan

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Abstract

The purpose of this study is to analyze the economic spillover effects and environmental impact of building offshore wind turbines on a local economy in Japan. Japan is facing a great turning point in its energy policy in the wake of the Great East Japan Earthquake, further increasing the importance of renewable energy. The offshore wind turbines experiment in Kitakyushu City is anticipated to showcase the potential of offshore wind power in Japan for the future and dynamize the local economy. As such, in this study, an economic and environmental impact assessment by Input–Output (I-O) analysis was conducted for the construction of the offshore wind turbines. The results show that building one hundred 3MW offshore wind turbine units will increase the induced production value by approximately 205.2 billion yen, equivalent to roughly 2.7% of Kitakyushu City's total production value. Additionally, it is anticipated to create approximately 14 500 jobs. In terms of environmental impact, the increase in production is estimated to increase CO_2 emissions by nearly 340 000 tonnes (an increase of approximately 2.1%). Accordingly, the environmental impact of building offshore wind turbines in Kitakyushu City is smaller than the economic impact, meaning that a sustainable between the economy and the environment can be found by the diffusion of renewable energy.

Keywords: offshore wind power, input-output (I-O) analysis, economic spillover effect, co2 emission

1. Introduction

The Framework Proposal for the Long-term Energy Supply-Demand Outlook sets, premised of safety, specific policy goals concerning the 3E+S policy: (1) increasing the self-sufficiency rate above the level before the Great East Japan Earthquake (approx. 25%), (2) lowering electricity costs from the current level, and (3) leading global efforts by pursuing Greenhouse Gas (GHG) emission reduction goals that match those for Western countries. Accordingly, as the energy supply-demand outlook for 2030, the Draft Framework set the final energy consumption at 326GL of crude oil equivalent, primary energy supply at 489GL, and self sufficiency rate at 24.3%. Energy-related CO_2 emissions were estimated to be 25% lower than 2013 levels (down 21.9% from the total GHG emission levels for 2013. (Yanagisawa, 2015; Kanekiyo & Ishimura, 2012; Toyoda, 2013)

Triggered by the Fukushima Daiichi nuclear power accident in 2011, comparisons of the costs of power generation for a range of power generation methods, including nuclear, thermal and renewable power, suddenly started to receive public attention in Japan (Matsuo, Yamaguchi & Murakami, 2013).

The current Strategic Energy Plan approved by the Cabinet states that the introduction of renewables should "surpass the level indicated based on the previous Strategic Energy Plan (approx. 20% by 2030)". If 20% seems already achievable, it may seem easy to surpass this figure. However, the barriers start getting higher beyond this point. First, there is the issue of the connection limit for variable electricity sources such as wind power and solar PV. The limit could be eased to a certain extent by improving the output curtailment rules and the rules for the usage of inter-regional transmission lines, but to go beyond that point, the only available options would be time-consuming and expensive ones, such as enhancing the inter-regional transmission lines and using storage batteries. Further, with solar capacities licensed at higher purchase prices due to be connected in the next few years, the surcharge will continue to rise. Depending on how the surcharge behaves, the current promotion policy itself may need to be revised considerably. Indeed, at the Subcommittee meeting, many pointed out that although it is important to promote carbon-free renewable electricity sources, their impact on electricity tariffs needs to be minimized (Hoshi, 2015; Frankl, 2013; Murakami, 2014; The Institute of Energy Economics, Japan, 2014).

The New Strategic Energy Plan (2014) gives specific initiatives for renewable energy. Founded on proper application of feed-in tariffs (FITs), it promotes future deregulations, such as shortening environmental assessment periods. Also, research and development for lowering costs and increasing efficiency, development and verification for large-scale storage batteries, power transmission and distribution grid development, and other initiatives will be actively pursued to deal with the issues of high power generation costs, output instability, and location constraints (Ministry of Economy, Trade and Industry, 2014).

Meanwhile, given the scarcity of suitable sites in Japan for onshore wind power, power generation technology for offshore locations with plentiful wind is being developed to further expand wind power. In addition to the fixed-foundation offshore wind turbines mainly used to date, development has recently started on floating offshore wind turbines. Fixed-foundation turbines are structurally limited to depths of approximately 30m, which is restrictive in Japan, where there are few shallow sea areas. Floating turbines are expected to see use in the future as they can be installed in deeper waters (Agency for Natural Resources and Energy, 2014).

As such, the this analysis is to quantitatively estimate the spillover effects that adding offshore wind turbines in Kitakyushu City will have on the local economy by using Input-Output (I-O) analysis. The CO_2 emissions associated with the induced production will also be measured to analyze the environmental impacts.

2. The Offshore Wind Power of EU and Japan

In 2014, 1483MW of new offshore wind capacity came online in Europe, a 5.34% decline over the 2013 market. The total now stands at 8045MW, and offshore wind power installations represented 12.6% of the annual EU wind energy market in 2014, down from 14% in 2013.

Overall, 408 new offshore wind turbines in nine wind farms and one demonstration project were fully grid-connected at the end of 2014. 54.8% of all new capacity was installed in the UK (813 MW). The second market was in Germany (529MW or 35.7%), followed by Belgium with 141MW(9.5%) (Global Wind Energy Council, 2015).

At present, the UK has 55.9% of all installed offshore wind capacity in Europe (4494.4MW). Denmark follows with 1271MW (15.8%). With 1048.9MW (13% of total European installations), Germany is third, followed by Belgium(712MW:8.8%), the Netherlands(247MW:3.1%), Sweden(212MW:2.6%), Finland(26MW:0.3%), Ireland(25MW), Spain(5MW), Norway(2MW) and Portugal(2MW) (see Table 1).

Table 1. Number of wind farm, turbines connected at the end of 2014 in Europe

Country	BE	DE	DK	ES	FI	IE	NL	NO	PT	SE	UK	Total
No. of frarms	5	16	12	1	2	1	5	1	1	6	22	74
No. of turbines	182	258	513	1	9	7	124	1	1	91	1301	2488
Capacity installed(MW)	712	1049	1271	5	26	25	247	2	2	212	4494	8045

Source: The European Wind Energy Association (2015).

The UK continued to lead the world's offshore industry in terms of both annual and cumulative installations in 2014, with as much installed capacity as the rest of the world combined.

The challenge of a new financial regime means that less offshore wind is likely to be installed by 2020 than had previously been expected. The Contracts for Difference are underpinned by a Levy Control Framework which will limit the expansion of offshore wind, particularly if costs remain at current levels; therefore developers have a strong commitment to reduce costs.

Provided a clear long term market which allows for cost reduction is evident, prospects for offshore wind remain very strong due to the UK's excellent resources and fully established supply chain. There is no formal target for offshore wind in the UK, but the government's renewable energy roadmap envisages a minimum of 9GW by 2020(GWEC, 2015).

Otherwise, The German offshore wind market surpassed the one gigawatt mark in 2014, more than doubling both 2013's annual market and the country's cumulative offshore capacity. In 2014, 142 offshore wind turbines totaling 529MW came online bringing the total number of offshore wind turbines located in the North and Baltic Seas up to 258, and the total offshore capacity in Germany up to 1049MW(see Figure 1).

In 2015, up to 2GW of offshore wind capacity is expected to be connected to the gird, bringing total offshore capacity up to 3GW, corresponding to and investment of EUR 10billion in the German offshore wind market. The largest wind farm to be fully completed during the first quarter of 2015 will be the Global Tech 1 wind farm with 400MW. It is expected that Germany will be by far Europe's leading offshore market in 2015(GWEC, 2015; Iwamoto, 2013; Iwamoto, 2014).

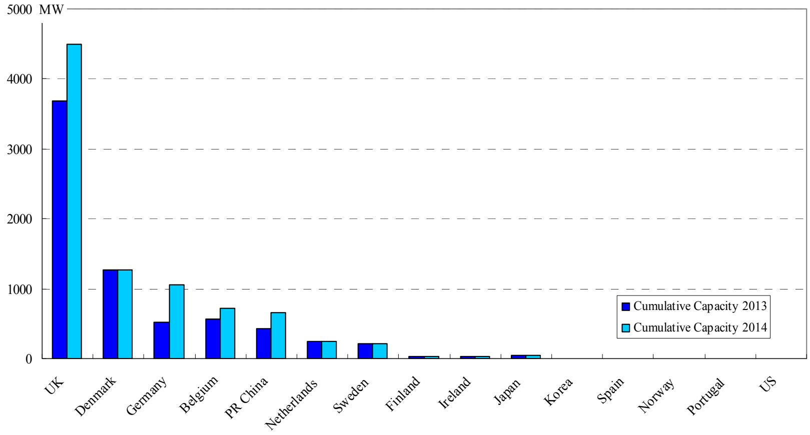

Figure 1. Global Cumulative Offshore Wind Capacity in 2014

Source: Global Wind Energy Council (2015).

In Japan, 49.6MW of offshore wind power capacity is currently installed: 4MW floating; 4.4MW on fixed foundations; and 41.2MW of semi-offshore wind turbines. One 3MW semi-offshore wind turbine will start operation in the first half of 2015 at Akita port and one 7MW floating offshore wind turbine is due to start operation in the summer of 2015 as part of the Fukushima FORWARD project. The Fukushima floating turbine will be located 20km from the coast (Frankl, 2014).

The Fukushima FORWARD project is a national government led project but the four others are commercial projects (see Table 2). The Kashima, Ishikarishinko and Mutsuogawara projects are located in designated areas (i.e. port areas). Currently there is no law or regulation for offshore wind power development in Japan for undesignated areas. The JWPW has begun discussion with lawmakers in the Daichi Tokyo Bar Association to address this gap in necessary regulations (GWEC, 2015).

Table 2. Offshore wind power projects in the pipeline in Japan

Project name	Location	Output(MW)	Wind turbines(MW)
Fukushima FORWARD	Fukushima	14	5-7
Kashima Port No.1	Ibaraki	125	5
Kashima Port No.2	Ibaraki	125	5
Yasuoka	Shimonoseki	60	4
Ishikarishinko	Hokkaido	100	2.5-5
Mutsuogawara	Aomori	80	2.5

Source: Global Wind Energy Council (2015).

In 2013, fixed-foundation offshore wind turbine demonstration units started running offshore in Choshi in Chiba (March), as well as in Kitakyushu in Fukuoka (June). Along with the data analysis and verifications, ultra large-scale wind power system technology and offshore wind power observation technology are being developed (Agency for Natural Resources and Energy, 2014). Based on these data and demonstration cases overseas, FIT has been enhanced since fiscal 2014 with new price classifications. Also, with the aim of commercializing floating offshore wind turbines by around 2018, but in any case as quickly as possible, technology is being developed, and safety and economic evaluations and environmental assessment methods are being established (Ministry of Economy, Trade and Industry, 2014; Shibata, 2014a; Shibata, 2014b).

3. Analysis methods

3.1 Analysis Outline

In the analysis, we used Leontief's I-O model to quantitatively estimate the spillover effects that construction sector investments have, both direct and indirect, on inducing production in other industries, employee income, and value-added. Equation (1) was used to determine the induced production value by individual final demand items when final demand is exogenously changed by construction of additional power stations.

$$X = \left[I - \left(I - \hat{M}\right)A\right]^{-1}\left[\left(I - \hat{M}\right)F + E\right] \tag{1}$$

where the terms are defined as follows:

$[I - (I - \hat{M})A]^{-1}$: Leontief inverse matrix

A : Input coefficient matrix

$(I - \hat{M})$: Self-sufficiency ratio

$\hat{M}$: Diagonal matrix of inflow coefficients

F : Final demand inner-city

E : Outflow

Here, the flow of analysis for economic spillover effects is as follows:

[Direct effects] The amount of new demand (construction sector) that local city production can supply itself is calculated.

Direct effect value = Demand amount × Self-sufficiency rate

[Primary spillover effect] Portion of direct effect value for induced production value from raw materials being purchased in Kitakyushu City is calculated.

Primary spillover effect = Inverse matrix coefficient × Direct effect value

Note that primary spillover effect includes direct and indirect effects.

[Secondary spillover effect] Production spillover effect from employee income (increased consumption) from the primary spillover effect is calculated.

1) The increase in employee income due to the primary spillover effect is calculated.

Employee income = Induced production value × Input coefficient for employee income sector

2) Portion of employee income used for consumption (demand) is calculated.

Induced private consumption value = Employee income × Consumption conversion factor

3) Induced private consumption value met by local city production is calculated.

Induced private consumption supplied locally = Induced private consumption value × Self-sufficiency rate

4) Value of production induced by induced private consumption value is calculated.

Secondary spillover effect = Induced private consumption value met by local city production × Coefficient of induced production value by individual final demand items

[Gross value-added inducement] Level of value-added inducement by induced production is calculated.

Gross value-added inducement = Induced production value × Input coefficient for gross value-added sector

[Induced labor] Amount of labor required to perform the induced production activity is calculated.

Induced labor amount (people) = Induced production value × Labor coefficient

In addition, the CO_2 emissions per unit of production in the *j*th sector are defined as follows:

$$c_j = CO2_j / X_j \quad (j = 1,2,...,n) \tag{2}$$

c_j : CO_2 emission coefficient

Equation (2) expresses CO_2 emissions per unit of production for each sector. When this is multiplied by Equation (3) to obtain

$$CO2 = \hat{c}[I - (I - \hat{M})A]^{-1}[(I - \hat{M})F + E] \tag{3}$$

it is possible to calculate the induced CO_2 emissions that emerge directly and indirectly, and use this result in an environmental analysis.

This analysis involved a simulation of the economic spillover effects and environmental impact of building one hundred 3MW offshore wind turbine units in Kitakyushu City as a renewable energy resource. Note here that the 2005 Kitakyushu City I-O tables and GHG emissions were used, with 34 industry sectors (Kitakyushu City of Japan, 2005a; Kitakyushu City of Japan, 2005b; Ministry of Economy, Trade and Industry, 2010).

3.2 Analysis Conditions

· Technical progress was ignored as technical levels (input coefficient) were constant at 2005 standards.

· Analysis results are in 2005 prices, with any price fluctuations between 2005 and now being ignored.

· The effects of economies of scale are ignored. As a linear proportional relationship is assumed for production and input in the I-O model, the effects of mass production are ignored. Input will double if production doubles.

· Kitakyushu City is assumed to have sufficient production capacity to expand production with increased investments, and thus imports from outside the area are not considered for meeting the demand requirement.

· No inventory adjustments are considered. Increased demand leads directly to increased production, and no measures for excess inventory (stock reduction) are considered.

· As no labor coefficient was available for the Kitakyushu City data, the coefficient from the Fukuoka Prefecture employment table (2005) was substituted(Fukuoka Prefecture of Japan, 2005).

· As no detailed CO_2 emissions data by industry sectors in Kitakyushu City were available, emissions were assumed to be distributed proportionately to sector production figures.

4. Results

In addition to induced production, the spillover effects of induced value-added, induced labor, and induced CO_2 from induced production were also measured for this analysis. Primary and secondary spillover effects are as shown in Table 3.

First, the estimated induced production effect for building one hundred 3MW offshore wind turbine units in Kitakyushu City is approximately 205.2 billion yen. Looking by sector, effects are biggest in the construction sector at 121.0 billion yen, followed by the business and service sector at 12.2 billion yen and the commercial sector at 11.6 billion yen. Effects are greatest in the construction sector because of the large direct and indirect impacts of investments for offshore wind turbine construction on sector production activity.

Next, looking at induced value-added effect, citywide value-added effects of approximately 94.7 billion yen are expected, 51.4 billion yen of which would be value-added in the construction sector. Induced employment effect would be approximately 14 500 induced hires, 9400 of which would be hired in the construction sector. However, these are at most 0.6% of the total jobs in Kitakyushu City, and so the employment effects are limited.

Elsewhere, the incidental environmental load from the induced production effect is another important point. Looking at the induced CO_2 emissions effects, the citywide increase in CO_2 emissions is expected to be approximately 340 000 tonnes. The rate of change is approximately 2.1%, which is less than the increases in production value and value-added at 2.7% and 2.5%, respectively.

Accordingly, the environmental load and impact of building offshore wind turbines in Kitakyushu City are smaller than the economic impact, meaning that a balance between economy and environment can be struck with the application of renewable energy.

Table 3. The Economic Effect and CO_2 Emission Effect by the Offshore wind power

		Production inducement effect(million yen)			Other spillover effect(million yen, person)						CO_2 inducement amout(1000 tCO_2)
		Production inducement amount(a+b)	Primary spill over effect(a)	Secondary spillover effect(b)	Value added inducement amount(c+d)	Primary spillover effect (c)	Secondary spillover effect(d)	Employee inducement amout(person)(e+f)	Primary spillover effect(e)	Secondary spillover effect(f)	
1	Agriculture, forestry and fishery	104.3	25.9	78.3	52.4	13.0	39.4	4.2	1.0	3.2	0.4
2	Mining	46.5	39.9	6.5	31.0	26.7	4.3	1.4	1.2	0.2	0.2
3	Foods	836.2	4.7	831.5	365.7	2.0	363.6	31.0	0.2	30.9	3.5
4	Textile products	75.3	35.5	39.8	29.6	14.0	15.7	7.4	3.5	3.9	0.3
5	Pulp, paper and wooden products	1167.6	1089.5	78.1	383.9	358.2	25.7	73.5	68.6	4.9	4.9
6	Chemical products	401.3	242.8	158.5	189.1	114.4	74.7	5.5	3.3	2.2	1.7
7	Petroleum and coal products	321.0	243.7	77.3	45.4	34.5	10.9	2.7	2.1	0.7	1.4
8	Ceramic, stone and clay products	4729.6	4684.6	45.0	2405.1	2382.2	22.9	186.7	185.0	1.8	19.9
9	Iron and steel	3982.1	3942.1	40.0	1583.6	1567.7	15.9	31.3	31.0	0.3	16.8
10	Non-ferrous metals	397.7	386.2	11.4	195.4	189.7	5.6	11.9	11.6	0.3	1.7
11	Metal products	7043.8	6959.7	84.1	2429.2	2400.2	29.0	419.3	414.3	5.0	29.7
12	General machinery	467.8	444.4	23.4	166.5	158.1	8.3	18.8	17.8	0.9	2.0
13	Electrical machinery	335.3	253.9	81.4	85.2	64.5	20.7	16.2	12.3	3.9	1.4
14	Information and communication machinery	4.9	2.5	2.4	1.1	0.6	0.5	0.1	0.1	0.1	0.0
15	Electronical device and parts	89.8	69.3	20.4	44.8	34.6	10.2	1.7	1.3	0.4	0.4
16	Transportation equipment	150.0	52.8	97.2	53.3	18.8	34.5	1.3	0.5	0.8	0.6
17	Precision instruments	21.9	5.3	16.6	9.8	2.4	7.5	1.3	0.3	1.0	0.1
18	Miscellaneous manufacturing products	1858.9	1451.0	407.9	888.4	693.4	194.9	94.3	73.6	20.7	7.8
19	Construction	121 095.1	120 546.5	548.6	51 410.8	51 177.9	232.9	9469.4	9426.5	42.9	176.5
20	Electricity, gas and heat supply	2109.4	1070.2	1039.2	623.6	316.4	307.2	32.2	16.3	15.9	3.2
21	Water supply and waste management services	897.8	482.5	415.3	584.2	313.9	270.2	43.1	23.2	20.0	5.5
22	Commerce	11 641.6	7129.9	4511.7	7064.2	4326.5	2737.7	1091.0	668.2	422.8	7.1
23	Financial and insurance	6392.6	3749.3	2643.3	3615.9	2120.7	1495.1	277.2	162.6	114.6	3.9
24	Real estate	6651.2	772.6	5878.7	4853.8	563.8	4290.0	52.9	6.1	46.8	4.0
25	Transport	10 070.4	7659.0	2411.4	4729.8	3597.3	1132.6	607.5	462.0	145.5	31.6
26	Communication and broadcasting	3977.4	2549.1	1428.3	2113.2	1354.3	758.8	158.7	101.7	57.0	2.4
27	Public administration	403.4	249.0	154.4	273.0	168.5	104.5	23.6	14.6	9.0	0.2
28	Education and research	1270.1	515.9	754.2	896.5	364.2	532.3	97.4	39.6	57.9	0.8
29	Medical service, health and social security and nursing care	957.2	0.9	956.3	538.9	0.5	538.5	81.7	0.1	81.7	0.6
30	Other public services	540.7	155.1	385.6	333.4	95.6	237.7	48.2	13.8	34.4	0.3
31	Business services	12 204.2	10 511.5	1692.7	7041.7	6065.1	976.7	1163.2	1001.9	161.3	7.4
32	Personal services	3662.6	99.7	3562.9	1911.4	52.0	1859.4	445.4	12.1	433.3	2.2
33	Office supplies	197.4	139.8	57.6	0.0	0.0	0.0	0.0	0.0	0.0	0.1
34	Activities not elaewhere classified	1133.4	1005.5	127.9	-181.9	-161.4	-20.5	6.5	5.8	0.7	0.7
	Total	205 238.1	176 570.4	28 667.7	94 767.9	78 430.4	16 337.5	14 506.8	12 781.9	1724.8	339.3

Source: calculated by author

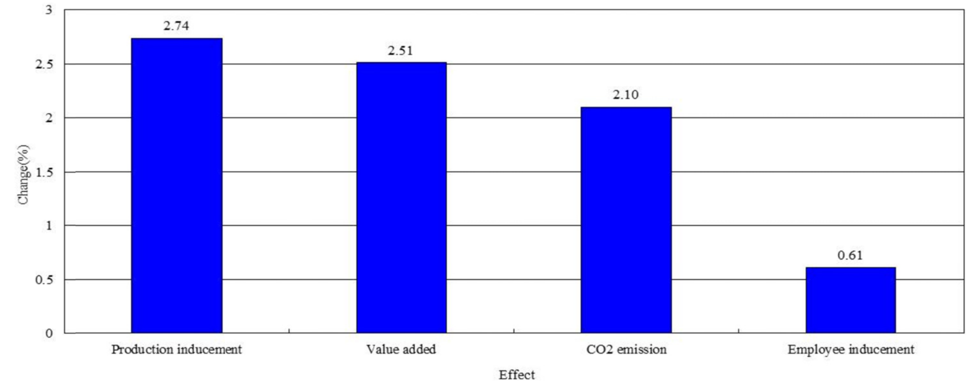

Figure 2. Change of Economic Effect and CO_2 Emission by Kitakyushu City (%)

Source: figured by author

5. Discussion

Currently, Japan has important policy issues concerning energy supply stability and reducing GHG emissions that need to be addressed. To do so, the Japanese government aims to reduce emissions by 3.8% from 2005 levels by the year 2020, and in the long term to reduce emissions by 80% by the year 2050.

At the same time, because of Japan's aging society and declining population, regional revitalization tapping into the features of each region is another important government issue. Taking another look at the current situation in Kitakyushu City through this filter, the city's population fell 9.2% from 1.07 million in 1979 to 970 000 in 2012. Total production peaked at 3.94 trillion yen in 1997, but has since fallen 13% to 3.43 trillion yen in 2010. Employee figures peaked at 539 000 in 1975, but have fallen 17.6% to 444 000 in 2012, a drop of 95 000 workers. In these tough economic conditions, Kitakyushu City has plans for a Future City Initiative as its regional revitalization strategy. As part of this plan, the city is working on the Project to Promote Establishment of Kitakyushu City as a Regional Energy Hub to realize a low-cost and stable energy supply with the aim of creating new jobs with a large-scale introduction of offshore wind turbines.

However, clearing the requirements for making the city a base harbor for offshore wind power is also important. These requirements include the following: heavy load platforms that will not be subject to ground subsidence, securing a sufficiently large area of land, securing a verification testing area, gathering industrial clusters of small- and mid-sized enterprises, and securing an emergency rescue helicopter and high-speed lifeboats. Although Kitakyushu City has yet to clear all requirements, the region is appropriate in terms of site conditions and industry requirements.

Issues remain for offshore wind power generation to fulfill its role as a renewable energy. First is cost. As offshore wind turbines are installed at sea, the installation costs are expected to be twice as much as those of onshore installations, because of costs for the wind turbines and the foundations (underwater portion of the base), as well as installation costs for submarine cables. Management costs are also higher than for onshore installations, and the installation costs increase with distance from the shore and water depth (New Energy and Industrial Technology Development Organization, 2013). The second issue is maintenance skill and human resources. While usage rates are higher due to steady winds at sea, there are indications that turbine failures are increasing globally as turbine size increases (Kondo, 2013). Technical innovations in generation equipment construction and securing maintenance skill are two important issues for the expansion of offshore wind power. Third is environmental impact. Excavation work during the preliminary survey and foundation work for offshore wind turbines can impact the ecosystem of seafloor life and sea products, and construction noise can impact fish reproductive behavior and survival rates. For birds, the turbines can take away their feeding grounds and resting places, and the birds can collide with the turbines (Kazama, 2012). Fourth is consideration for local industries. The requisite awareness of local fishermen makes it important to conduct offshore environmental assessments and disclose all information.

This study was a quantitative analysis of the economic spillover effects and environmental impacts of building offshore wind turbines. Moving forward, a multifaceted study factoring in future changes to population composition and lifestyles will be required. What this means is that an increase in supply of renewable energy from offshore wind turbines and other sources will impact the overall energy supply–demand structure, consequentially reducing fossil energy consumption and CO_2 emissions to a certain extent. Given this, an analysis of the overall energy structure and industrial compositions is required. Further, as this analysis used I-O tables from 2005, care must be taken to note that the analysis does not reflect the 2008 global financial crisis or the Great East Japan Earthquake, two events with great social impacts. This will be a point for future study.

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